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ENTILATION

OF

BUILDINGS.

BY

W. F. BUTLER.

NEW YORK:
D. VAN NOSTRAND, PUBLISHER,
23 MURRAY AND 27 WARREN STREET.
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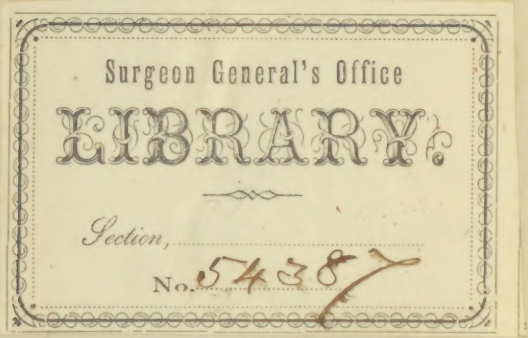

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VENTILATION OF BUILDINGS.

I do not claim to have discovered anything new in the art of ventilation. All I have endeavored to do in the following pages is to lay down principles, which shall be applicable to almost every case where ventilation is required.

One object of the paper is to insist upon the great and increasing importance of the subject, and, if successful in this, I am satisfied that it will not have been read in vain.

Before proceeding further, I think it will be desirable to explain what I mean by the term "Ventilation." Briefly, it is this,—a gradual, continuous and complete changing of the air contained in any structure, a substitution, in fact, of fresh air for foul, but so gradual a substitution that the motion of the air should be imperceptible.

Of course, in factories, imperceptibility

need not be so much regarded, and in the cases of sewers and underground railways, it is obvious that any method may be followed which promises the most perfect results.

The importance of the subject under consideration, which can hardly be overestimated, has been the constant theme of writers on ventilation; thus, Dr. James Johnson, in a work called "A Diary of a Philosopher," says that all the deaths resulting from fevers are but as a drop in the ocean, when compared with the numbers who perish from bad air.

It is to the efforts of science that we must look for an alteration in so disastrous a state of things, and men of science may be assured that Society will ere long demand, not, as an eminent Philosopher is reported to have said, a new faith—we neither look for nor expect that—but a longer life, increased freedom from disease, and greater means of enjoying sound health while life lasts.

I believe, we cannot doubt that much of the apathy manifested towards our subject

by people generally, results from the abortive experiments and useless methods so often tried, and resorted to for the purpose of supplying the want of ventilation.

Before I leave this part of my subject, I will mention one other difficulty in the way of ventilation, and this by no means a small one—I mean the cost.

Although efficient ventilation will not cost a very large sum per room, it cannot be denied that somewhat will be added to the expense of the house, and this "somewhat" the speculative builder never will add until he finds intending tenants and purchasers refuse to take houses which are not properly ventilated.

As with houses, so with all other buildings and works; if we make up our minds to ventilate them, we must also resolve to pay for it.

I fear that even persons who build houses for their own occupation, are but little in advance of the speculative builder, as far as any recognition of the absolute necessity of efficient ventilation is concerned. Many hold to such crude devices

as open windows and doors. Others think a hole of any size or in any part of the wall quite sufficient, while, I believe, the majority pooh-pooh the whole question.

It then becomes the duty of scientific men, and bodies, to educate the public up to the recognition of the fact, that ventilation is every whit as important as drainage, to individual houses, and that man can no more live in a foul atmosphere than he can while constantly imbibing poisonous water.

Ventilation is a want arising chiefly from modern ways and customs, and is therefore a comparatively new branch of science, and we owe our present knowledge of the subject especially to modern researches and discoveries.

That ventilation is a new requirement will, I think, be readily acknowledged, when we consider the every-day life of our forefathers who lived prior to the close of say the 17th century. We shall see that, in by far the larger number of cases, theirs was an out-of-door life. Their days spent mostly in the field, either in the sports of

the chase, in war, or in the occupation of husbandry.

If they were wealthy, their halls were large and lofty with enormous fireplaces, and loosely fitting doors and windows, from which innumerable currents of air rushed to the fires. If they were poor, they had, amid all the dirt and wretchedness which surrounded them, no want of air, as any one who has seen an old English or Welsh Cottage will readily admit.

The windows, too, down to nearly the period I have named, were, in most cases, filled with nothing better than shutters or louvre boards, glazing being then a rarity, at least in houses of the commoner sort, for though glass was known to the Phœnicians and to the later Egyptians, whose glass works at Sidon and Alexandria were famous throughout the then civilized world, and although it was employed by the Romans to some extent in their windows, as is shown by the remains found in Herculaneum, window glass was not manufactured in England, I believe, prior to the middle of the 16th century and must up to

that time at least, and probably long after, have been an article of luxury, while its substitutes, oiled paper or plates of horn, can hardly have been in general use, at least in the dwellings of the poorer classes in country districts.

In cities and towns, doubtless, greater comfort, if not better sanitary arrangements, prevailed. But these were always the strongholds of fever, plague, and cholera. In towns the "black death," so much dreaded in the 14th century, had its headquarters, and from them it extended its devastating arms into all the surrounding country. I believe that to defective ventilation not less than to bad drainage and insufficient water supply, may be traced these scourges of the human race which now seem rapidly giving up their strongholds to the invading forces of science.

We cannot wonder on looking at such places as the hall of Bodiam Castle, for instance, in which were two fireplaces, each about 25 ft. wide and 7 ft. high, that people found a settle, a comfortable article of domestic furniture, and viewed the chimney

corner, where they crowded like smoked hams, as the choicest parts of the room. Nor must we be surprised when we are told that the curtains enclosing the couches whereon reposed the proudest beauties of the land shook in response to every wind that blew.

If the wretched hole which they show in Carnarvon Castle as the birthplace of Edward II. be indeed the room in which that unhappy prince first saw the light, I can only say that whatever advantages the men of a former age may have had over us, certainly domestic comfort could not be said to be one of them.

The first person who seems to have turned his serious attention with any practical result towards the subject of this paper, at least in England, was, I believe, Dr. Desaguliers, who, in 1723, was called in to ventilate the House of Commons, upon which Wren had before tried his hand.

The Doctor discharged his commission with success, but he unfortunately provoked the hostility of one very important individual, viz., the housekeeper, a certain

Mrs. Smith, who effectually extinguished him by not lighting the fires upon the action of which his system depended, until the House had sat for some time, and the chamber had got thoroughly heated, so that we cannot wonder some of the members should have considered the design of cooling the House was frustrated, and requested the Doctor to employ other means. He accordingly invented a centrifugal wheel, or blowing machine, so constructed as to force air either into or out of the House, according as either was required. This machine was put in charge of a man called the ventilator, whose duty it was to wait upon Mr. Speaker every day for orders. Dr. Desaguliers was next applied to by the the Admiralty to ventilate ships, but here, as might be expected, he got inventors' allowance, viz., more kicks than halfpence. All his troubles with Mrs. Smith were nothing compared with the treatment he and his invention received from Sir Jacob Ackworth, the Surveyor to the Navy, who seems to have been the beau ideal of an official. When the Doctor attended by appointment

on board the ship in which his machine was to be tried, Sir Jacob did not appear, but hearing that the company were pleased afterwards told Dr. Desaguliers that at the next experiment he (the Doctor) need not attend, as the carpenter could manage the ventilation.

When the second trial came off, Sir Jacob had scuttle holes cut at each end of the ship and then hoisted enormous windsails, and when, as might naturally be expected, he found that more air came through his windsails, which were about 2′.6″ diameter than through the Doctor's tubes, which were 5″×3′; he said he could not stay longer, and that he was sorry the machine had answered no better. Sir Jacob, however, sent his "humble duty" to Dr. Desaguliers, and thought his invention might be a very pretty thing in a house.

The Lords of the Admiralty never came near nor gave themselves any trouble about it, and so the Doctor found his invention would not be used in the Navy.

The next person who came forward in the cause of ventilation for the Navy, was

Mr. Sutton, a brewer by trade. He made use of the fire which cooked the provisions of the ship's company as the motive power, laying pipes from all parts of the ship to the ashpit under the grate. When the ashpit-door was closed no air could get to the fire except throught the pipes.

The result was considered satisfactory, and the apparatus was ordered to be fitted up on board the Norwich man-of-war.

Mr. Sutton had also to contend with Sir Jacob Ackworth, but he had found powerful friends in Dr. Mead, the King's Physician, and Sir Charles Wager, so that the old knight's opposition was rather passive than active.

This, I believe, is one of the first, if not the first, instance of the scientific use of the common fire as the power for ventilating any structure. This method has been called thermo-ventilation by Mr. Bernan, to whose work, as well as to those of the inventors whose names I have mentioned, I am indebted for many of the particulars given above.

However successful Mr. Sutton may have

been in getting his apparatus fixed, he failed when he applied to the Admiralty for some reward for his sevices; they simply took no notice of him or his petition, although the Norwich had returned to England from the Guinea Coast, with the loss of only two men, and the Captain reported her singularly healthy.

Meanwhille, a certain Dr. Hales had been pressing an invention of his own upon the notice of my Lords. This he called a ship's lungs. The machine was, in fact, a magnified bellows, differing somewhat in construction from common bellows certainly, but the same as far as action was concerned. It consisted of a large square case with valves, enclosing a hinged midriff, which rose and fell by the action of a long handle or lever, worked by some of the ship's company. The whole machine was cumbersome, requiring about four men per hour to work it, and could not, certainly, compare with the blowing-wheel of Dr. Desaguliers. It soon fell into disuse, and became a thing of the past.

Mr. Sutton, who had at last got £100

from the Admiralty, exulted over the failure of the ship lungs, but his triumph was short-lived, for, in the course of a few years, he found that he was left out in the cold also, and the old wind-sails were again on duty.

The illustrious names of Count Rumford and Sir H. Davy, as well as those of a host of other persons less celebrated, which figure in the annals of ventilation, attest the importance of the question. It is time, however, for me to take leave of this portion of my subject, on which volumes might be written, and to consider the causes which make ventilation a necessity.

These may be classed under different heads, viz.: 1st, In private houses. The necessity for ventilation will arise from commonly (A) the presence of fires; (B) artificial light; (C) the presence of persons living in the house, that is from the air required by them, as well as the exhalations from their bodies, and (D) from badly constructed water-closets, cesspools and drains. 2d. In factories there will be, in addition to the above causes, the presence in the air

of a vast quantity of minutely-divided fibre and dust, which is highly prejudicial to the health of the workers, and also the fumes from chemicals, etc., where the manufacture of such is carried on. 3d. In sewers. The necessity of sufficient ventilation will almost entirely arise from the generation of poisonous gases by the putrid filth carried down. 4th. And in underground railways, the fires of the engines, and the saturation of air by the waste steam, will render ventilation, in certain cases, necessary.

Considering these cases in the above order, we have 1st, in dwelling houses (A), the presence of fires.

At first sight it would seem an error to include this under the head of causes which make ventilation necessary. As fires are often, indeed mostly, the only means of ventilation in private houses. But under the term I include not only the removal of foul air, but the supply of fresh, and from this point of view it will be seen that the common fire is a very great consumer of fresh air, and requires a supply of that

quite as much as of the fuel which feeds it.

It may be as well to mention here some of the well-known facts connected with the combustion of fuel.

The fuels commonly used are composed, principally, of carbon and hydrogen in about the following proportions:—

Name.	Carbon	Hydrogen.	Ashes, &c.	Water.
Coal.....	.812	.048	.140	....
Coke.....	.850	...	.150	....
Wood.....	.408	.042	350	.200
Charcoal...	.930	....	.070	....
Peat.....	.464	.048	.288	.200

Now, combustion consists in the union of oxygen gas with the elements carbon and hydrogen, and the result is a development of light and heat, and the formation of carbonic acid and water, the carbon of the fuel uniting with the oxygen of the air to form carbonic acid, and the hydrogen doing the same to form water.

Carbon exists in its pure and crystallized form as the diamond, and this beautiful gem is combustible in oxygen gas, burning entirely to carbonic acid. This experiment

has been tried, however, only in the laboratory.

One pound of carbon requires for its combustion 158 cubic ft. of air, while the same weight of hydrogen requires 473 cubic feet. From these facts it will be seen that the different fuels mentioned above will take for their proper combustion the following minimum quantities of air, viz. :—

Coal	148	cubic feet	per pound.
Coke	134	"	
Wood	65	"	
Charcoal	147	"	
Peat	81	"	

There is a certain quantity of oxygen in coal, wood, and peat, which somewhat reduces the amount of atmospheric air required by these fuels.

From the above tables—for which I am indebted to the researches of Péclet, Playfair, Regnault, and others, and which assume the temperature of the air to be 26 deg. F.—it will be seen that the ordinary fire plays no unimportant part in the consumption of air; for, if we assume one pound of coal per hour as the quantity required, then 148 cubic ft. of air will be con-

sumed in that period, or 2.46 ft. per minute, or 2,072 cubic ft. per day of 14 hours.

These, as I have said, are minimum quantities. In practice, at least double must be allowed, as a large percentage will escape unconsumed.

In the case of the common fire, the products of combustion do not certainly escape into the room, but the air to supply the fire is required all the same, and I feel sure that not in one house in a hundred is this supply ever thought of, but is left to chance, and the cracks in the doors and windows from which drafts whistle across the room in every direction.

The second cause (B)—artificial light—requires far more serious consideration than the fire, for, commonly, the products of combustion are passed directly into the room, and are breathed in a diluted form by the persons in it.

The introduction of coal gas has been most pernicious in this respect, for few houses are built with any regard to the method of lighting, nor are the ways in

which the gas is generally burnt calculated for anything but to do the greatest amount of injury to the persons using it. Some forms of gas-light, such as the sun burners and the ventilating globe light, are comparatively free from defect in these respects, but I have never seen the latter used save in one or two private houses, and the former are almost entirely confined to offices and public buildings.

I have experienced some difficulty in obtaining the quantity of air consumed by the ordinary bat's-wing or fish-tail burner when lighted. But taking the Argand burner using 5 ft. of gas per hour, and 45 ft. of common air in the same time, as a standard, and knowing that the common burners burn from 2 to 6 ft. per hour, according to size and pressure, I think I shall be safe in calculating the average consumption of gas by the common burners at 4 cubic ft. per hour, and the amount of air at 36 cubic ft. per hour.

Now a room 25 ft. long by 16 ft. broad, and 10 ft. 6 in. high, will contain 4,200 cubic ft. of air, but a deduction must be made for

furniture, etc., of at least 10 per cent., leaving 3,780 cubic ft., or say 3,800, as the net quantity of air in the room.

Such a room will require at least three gas burners to light it, and these, as we have seen, will consume 108 cubic ft. of air per hour, rendering it absolutely unfit for breathing by depriving it of its necessary proportion of oxygen.

Ordinary candles do not vitiate more than 11 cubic ft. of air per hour, per candle.

As the chief constituents of coal gas are carbon and hydrogen, so the principal results of its combustion are carbonic acid and water. This water, in the form of vapor saturates the air of the room, which has a greater capacity for moisture when warm than when cold. This may be readily seen if, in a close warm room, we examine the windows, where the moisture will be found condensed, and perhaps running down the glass in streams.

The same effect will be produced by placing a glass bottle filled with cold water on the table, the moisture will settle thickly upon it like dew upon the grass on a clear night.

The reason is this. The air cooled by contact with the cold glass is no longer able to sustain the moisture, and the latter is therefore precipitated in the form of dew.

(C.) The third cause I have mentioned is the presence of living beings in the room. Let us now consider the effect of this.

Man's body is a furnace, a slow combustion furnace if you will, but still a furnace, and the waste from this human furnace is precisely the same as that from any other furnace, viz., carbonic acid and water. To quote the words of Professor Tyndall: "In the animal body the carbon and hydrogen of the vegetable are again brought into contact with the oxygen from which they had been divorced, and which is now supplied by the lungs. Re-union takes place, and animal heat is the result. Save as regards intensity, there is no difference between the combustion that goes on within us, and that of an ordinary fire." We see then of what vital consequence is the presence of oxygen in the atmosphere. Without it fires and lights will not burn, our food will not digest, and the blood

remains unpurified, as is shown by the pale faces and purple lips of people living in close warm rooms. These are the forerunners of certain death to persons deprived of the life sustaining oxygen.

Atmospheric air consists of a mixture of several gases, for though it is commonly said to be formed of oxygen and nitrogen in proportion of 21 volumes of the former to 79 of the latter, in each 100, yet several other gases are mixed with these. The composition of air varies with its situation. Thus, inland air is not of precisely the same composition as that near the sea coast, where there is said to be a greater proportion of ozone. On rocky mountains there is more carbonic acid than is found in the valleys.

The quantity of air required by a man varies with the state of his body. Thus a man at hard work or violent exercise may require even five times as much air as the same man when asleep.

This amount of air has been variously estimated, but I think we may safely take the following calculation by Box to be cor-

rect. He states that an ordinary man takes 20 respirations per minute, of the capacity of 40 cubic in. each, thus vitiating 28 cubic ft. per hour. Added to this, there is the quantity of air saturated by the moisture evolved to be considered. According to Dumas this quantity in the form of vapor equals .0836 of a pound of water per hour, which is sufficient to half saturate, for air should not be more than half saturated to be pleasant—187 cubic ft. of air at 62 deg. Fahr.

We thus see that to be in good health a man must have 215 cubic ft. of air per hour for his own use. Sick persons require very much more than this.

(D.) There is one more source of contamination of the air of our houses, which often forces itself unpleasantly upon our notice. I mean the foul gases which escape from drains and water-closets. It is not too much to say that if architect and builder always did their duty, no foul air from any drain or closet ought ever to enter a house, and that the negligence of one and the ignorance, or worse, of the other, must be

charged with a greater destruction of human life and with causing more disease every year than has been produced by the bloodiest battle recorded in history.

It is impossible to estimate correctly the air contaminated from this source, but I hope to show how such contamination may be avoided.

As a summary of results we see, that in a room of the net cubic capacity of 3,800 ft., having a fire burning, inhabited, by say six persons, and lighted by three gas lights, there will be required every hour, so that the inmates may be healthy, 1,694, or say 1,700 cubic ft. of fresh air at 60 deg. F.

But air expands $\frac{1}{490}$, or 0.00204, of its volume for every degree F. it is heated; it is obvious from this that, assuming the temperature of the outer air to be 32 deg. F., we shall not require to admit so much cold air into the room by about 100 cubic ft., but exit must be provided for the full quantity.

Professor Tyndall gives the following table of expansion of gases for an increase of temperature equal to 1 deg. F. :—

Hydrogen	0.00203
Air	0.00204
Carbonic Oxide	0.00204
Carbonic Acid	0.00206
Protoxide of Nitrogen	0.00207
Sulphurous Acid	0.00217

We see from this that gases obey the almost universal law, and expand with increased heat. Upon this fact is built the whole system of thermo-ventilation, and upon its due appreciation depends success in this particular branch; for it follows that as gases expand so are their densities decreased, and they are lifted upwards by the heavier air without; rising, not because they are light, but because the outer air is colder and consequently heavier.

The following is a table of specific gravities of gases taken from the experiments and researches of Regnault and others. Atmospheric air being 1 :—

Air	1.00000
Hydrogen Gas	0 06926
Oxygen Gas	1 10563
" "	1 11100
Nitrogen Gas	0.97137
Carbonic Acid	1 52901
" Oxide	0.9727
Protoxide of Nitrogen	1.5252
Sulphurous Acid	2.2464
Sulphuretted Hydrogen	1.1710
Vapor of Water	0 6235

This table shows us how varied are the densities of different gases. Thus, while hydrogen is more than 14 times lighter than air, sulphurous acid is about $2\frac{1}{4}$ times heavier.

There is another property of gases which merits our consideration besides that of density, and this is the power they have of mixing with one another.

The gases which compose common air, for instance, are not chemically combined to form any new substance ; they exist each one of them just as if the others were not present. When we consider this, and the fact that they are of different densities, it would fill us with astonishment that they do not settle, as it were, away from one another, the heavier oxygen falling to the ground, and the lighter nitrogen ascending to the clouds, did we not know of this law of combination, which is called the law of diffusion of gases. Professor Graham expresses this law by saying that *the diffusive power varies inversely as the square root of the density of the gas itself.*

A simple but beautiful experiment of the Professor's illustrates the law.

I have stated that in the room before mentioned we require at certain times—and all works should be calculated for the greatest possible duty they may have to perform—space for 1,600 cubic ft. of fresh air to enter, and far 1,700 ft. to leave the room every hour.

I am aware that any proposal to admit cold air into a room will meet with opposition, and were houses built upon principles worthy of our civilization it might easily be avoided. I think, however, that, with proper means, the possible evil may be so reduced as to be practically unfelt. I am also now treating of existing houses which could not well be rebuilt or altered.

I would propose that in such houses where the want of ventilation is felt, the openings for admission of fresh air should be made as near the floor of each room as possible. For it will be seen from what has gone before, that the cold air will, on entering, be heavier than that in the room, which it will gradually force upwards and out through the foul air exit channels.

Many people will probably say, "Oh

what a draft there would be to one's legs and feet." Doubtless if a good sized hole be cut through the wall, say directly opposite the fireplace, and you shut the door and stand between the opening and the fire, very likely you would feel rather cool about the inferior extremities. But I do not propose a thing of this kind.

The fire must have its own separate supply, which should be given by means of a pipe leading through the hearth-stone, as is sometimes done now, with the opening facing the fire, which latter, as it constantly acts the part of a pump, will take care to get its own allowance from the nearest source.

We have therefore only the forcing power of the difference in weight, between columns of air, of equal height, but of the different densities due to difference of temperature between the external air and that in the room. This difference I have assumed to be 30 deg.

This forcing power will cause the air to enter the room with a velocity equal to that which would be acquired by a body falling

a distance equal to the difference in height between a column of air 10 ft. 6 in. high at 62 deg., in the case I have assumed, and the same air at 32 deg.

This difference will be equal to .643 of a foot, and the speed of the entering current will, by the rule for falling bodies, be 6.43 ft. per second.

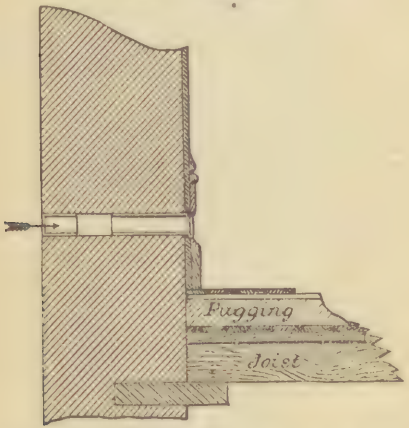
Assuming that all the air enters through one opening, then about 8 sq. in. would be sufficient. It will be obvious, however, that it is not advisable to admit air at so high a velocity as this, nor would one inlet be so efficient as several.

I would propose, then, for existing rooms, that the inlets should be made in the side walls, near the floor, and in as many different sides of the rooom as its situation will allow. That these be made larger towards the room, and that they should be enclosed by metal gratings made ornamental on the outer and inner faces. The sketch marked A will show generally what I mean.

There is one point to which I would call your particular attention, and this is the

fine wire gauze screen shown just behind the ornamental front. This serves a very useful purpose, for it screens and breaks up the entering current of air, preventing all drafts, and, if the openings have sufficient area, allowing the incoming air to mingle so gently with that now in the room, that its presence is not felt save in a pleasant way.

FIG. 1.—SECTION.

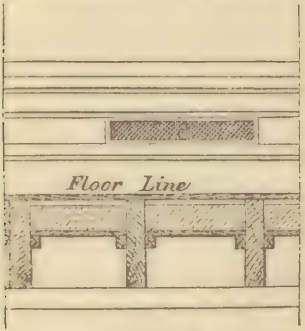


I attach great importance to this screen, and to the size of the openings.

We must now proceed to consider the best position for the exit.

I think a little consideration will show us that the heated chimney affords the best possible means under the circumstances. By causing the foul air to escape into the chimney we increase the ventilating power

FIG. 2.—ELEVATION.—A is the grating.



very considerably. We have no longer to deal with the small difference before mentioned, but may calculate upon the whole height of the chimney, above the opening, through which the foul air enters it, and have the difference between this column of air highly heated as it is, and that of

another of the density of the outer air, as the force at our disposal.

Care must be exercised in the choice of a valve to close this opening against down draft. The best which has come under my notice is formed of a series of leaves or flaps of mica enclosed in a metal case. The flaps are very light, and, being hung from the top, are absolutely secure against return currents. The front may be made as ornamental as can be desired.

The heated and spent air from the gas light should be conveyed away immediately when possible.

The ornamental flower which is commonly placed in the centre of the room may be pierced through. The opening thus formed being boxed in between the joists with thin sheet metal connected with a tube for conveying the waste gases into the chimney or outer air.

The register of the fire grate will form a regulator, by closing or opening which the draft through the escape valve may be increased or diminished.

Exercise of proper skill and judgment in

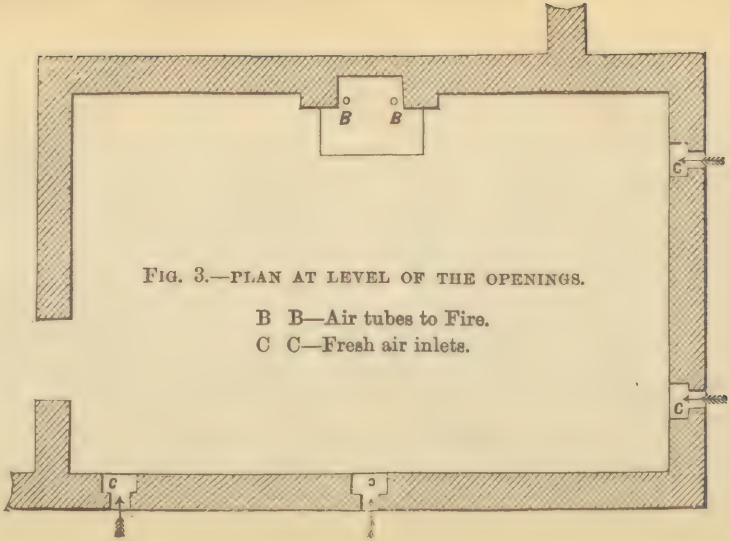


FIG. 3.—PLAN AT LEVEL OF THE OPENINGS.

B B—Air tubes to Fire.
C C—Fresh air inlets.

the form and placing of the inlets, and in the construction of the exit, will insure comfortable ventilation in rooms built with no special provision for it.

The tube which supplies the fire should have a valve to close it, so that when necessary the whole pumping power of the fire may be applied to sucking in fresh air through the room.

I will now refer to the last source of contamination mentioned above, viz., foul drains and water-closets.

Any unpleasantness from the former will commonly arise from faulty design, or malconstruction. A drain is ill designed which passes under any portion of the house, unlesss no other way is possible. Also where no provision is made for ventilating, and where it is not of ample size.

A drain unevenly laid, built of inferior materials badly jointed, or not properly connected with the main sewer, is badly constructed.

Of course, in use, a drain may become stopped by accident or design; this is another matter; all works are liable to acci-

dents, but a mishap of this nature will soon show itself by the bursting or overflow of the drain.

The remedies for bad smells from drains are, 1st, the proper laying of the drain. It should be formed of socketed pipes, in no case less than 4 in. diameter, 6 in. will often be better, or even 9 in. pipes for large houses. Sufficient fall should be given, not less, if possible, than 3 in. in 10 ft. The pipes should be laid in good concrete, and jointed with Portland cement. 2d. The drain must be trapped. The common siphon trap is the best form for general use, and I believe a single trap is preferable to double, for with two traps, when the water has passed the first it compresses the foul air, which escapes through the upper one into the house. 3d. All injurious escape may be prevented by ventilating the drain. A pipe should be connected with the siphon, on the summit of the bend between the water which closes the trap and the leg of the siphon which joins the drain. This pipe Dr. Carpenter says should be of nearly the same bore as the siphon, and should be carried up out-

side the house above the eaves, as far from any window as can be. Outside a chimney is a good place, but the opening should not be above or near the top of the chimney. Care must be taken to make the joints in the pipe gas-tight. The rain-water pipes should not be used as ventilators to the drains.

Unpleasantness from the water-closet will almost always arise from its position. This, as we all know, is commonly the very worst which could be found, viz., under or close to the stairs, the well of which forms a shaft for conveying foul air into all the bed-chambers.

I have seen in London a water-closet opening into the dining-room, but even this is hardly so objectionable as the usual position.

The water-closet should, where possible, be outside the house. I do not mean detached, but separated by such a space as will allow of double doors, with sufficient distance between them for ventilation.

The building itself should also be thoroughly ventilated.

I will now briefly state how a house might be built so as to be efficiently ventilated on the principle of thermo-ventilation.

It will be sufficient to take one room as a type of the rest, and I will assume that it is desirable to keep up the old-fashioned open fireplace, wasteful as it is.

The fresh air may be brought directly through the outer walls as in sketch B, or may be first slightly heated by passing through a hot water coil, or other apparatus.

If the former course be followed, air bricks must be inserted in the outer face of the walls communicating with a channel running round a portion or the whole of the room.

If warmed air is desired it must be brought into the channel through tubes in the wall.

The inner channel should be formed by a cast-iron box, with an ornamental open-work front, and without a back. The front, which may be of brass, should be fastened so as to be readily removable. The fine

wire gauze screen being fixed as shown in Fig. 2.

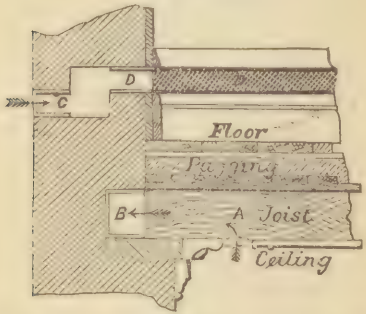
The exit for foul air should be through open work in the ceiling, as shown in Figs. 4,

Fig. 4.

5 & 6. This openwork might either be done in plaster similar to the centre ornament,

or fine brass wire gauze might be inserted in the cornice. The foul air would pass through this into the spaces between the joists, when the sound boarding and pugging will prevent its ascending into the upper rooms. From these spaces it would pass into a cast-iron channel running round the room, which would communicate with the chimney or air flue, or in some cases directly

FIG. 5.—SECTION.



with the outer air. The openings into the chimney or air flue must be fitted with valves, as before.

I believe it would be easy to construct a chimney having all the advantages of a chimney and air flue combined.

A tube should be inserted in the brick trimmer giving immediate communication with the fire above, which, when lighted, would aid the ventilation of the lower room.

All large houses should have a special ventilating shaft, communicating by means of pipes and valves with every room in the house. If thermo-ventilation alone is intended, a fire must be kept burning at the base of the chimney, the only supply of air to which must come through the tubes.

Some day, perhaps, we may have ventilating shafts for every street or block of houses. We provide for the carrying away of foul water, why not of foul air? The one is just as harmful as the other. Perhaps, too, though this belongs rather to warming than ventilation, we may some day see but one fire to each house, and even one chimney. Nay I will go further, perhaps one chimney to a great number of houses, perhaps even one to a town! This may seem a speculative flight; but had coals been very dear instead of cheap, I feel sure our present wasteful system would not have lasted long.

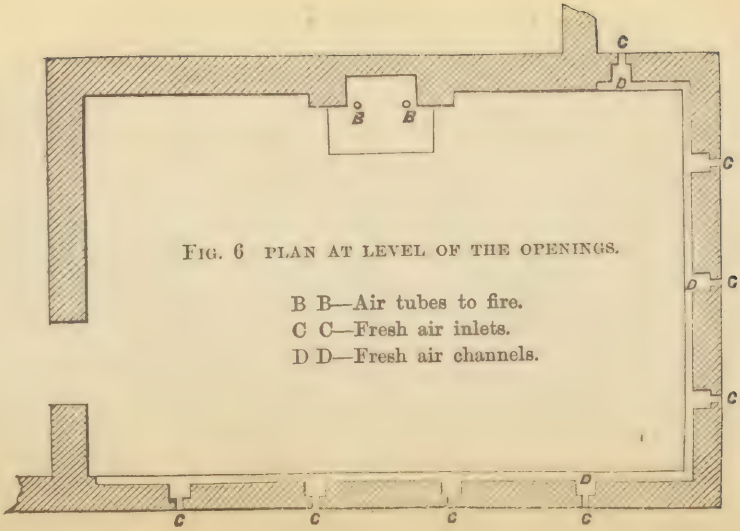


FIG. 6 PLAN AT LEVEL OF THE OPENINGS.

B B—Air tubes to fire.
C C—Fresh air inlets.
D D—Fresh air channels.

Before quitting the subject of house ventilation, I will notice one fruitful source of annoyance, which is often closely connected with defective ventilation, I mean smoky chimneys. Want of air causes perhaps more chimneys to smoke than any thing else, and before any one sets to work to alter the chimney in any respect, it is better to see whether it is not more air that is wanted. This may be easily done by trying the fire with a door or window open, and with the same shut. If in the latter case the fire smokes, while in the former it does not, then want of air is the cause. Care must, however, be taken, as to what window is open, as gusts of wind or a cross draught will often cause the fire to smoke.

For churches, schools and factories, thermo-ventilation may be used, but probably the fan, or blowing wheel, will, in many cases, be more efficient and economical.

I believe it is in use in some buildings in London with very satisfactory results.

Its useful effects will vary with the size of the wheel and the speed at which it is driven, and in designing a fan it should

be borne in mind, that a large fan and low speed is generally better than a small one and high speed, chiefly on account of the vibration caused by gearing running at great velocities. The motive power may be either steam, water, or a weight which can be wound up as occasion may require.

It is impossible here to even refer to many noxious manufactures, chemical and otherwise. But of this we may be sure, that if they are prevented by law from polluting the atmosphere, the science of chemistry is quite equal to finding a remedy, and even to converting the noxious fumes into useful products.

There is an objection to thermo-ventilation, which does not apply to the fan, viz., that, as it usually depends for action upon the difference in temperature between the inner and outer airs, so in summer it may come to a stop, or be even reversed.

This objection is not of much weight, as people are far oftener out in the air in summer, and at night when gas or candles are lighted ventilation would commence again.

A special shaft would preserve the action constant all the year round, though most active in winter.

The fan is probably the leading instrument in mechanical ventilation.

Box states that a fan 5 ft. in diameter running at a speed of 50 revolutions per minute will discharge 2,250 cubic ft. of air in that time, while a fan of 10 ft. diameter at 25 revolutions per minute will discharge 9,000 cubic ft.

The third case I mentioned above was that of sewers. It may be considered established that the exhalations from fresh sewage are not injurious, but it is equally sure that those from putrid sewage are highly poisonous. Of all of them sulphuretted hydrogen may be fairly considered the most deadly. This gas is slightly heavier than air, hence it is more difficult to remove than the lighter gases.

According to Thénard, a proportion of $\frac{1}{1500}$ of sulphuretted hydrogen in the air will kill a bird, $\frac{1}{1000}$ a dog, and $\frac{1}{250}$ a horse.

Some of the gases generated in sewers

are explosive when mixed with the atmosphere, hence it would be dangerous to introduce them into factory chimneys. The experiment was tried in Southwark with the blowing up of the furnace as the result. With sewers, as in other cases, ventilation must be subject to modifications.

In villages and small towns where pipe sewers are alone employed, small ventilating shafts carried up the nearest building, tree, or other suitable object, will answer the purpose, viz., that of relieving the sewers of any pressure of gas.

Their useful effect will be increased by the Archimedean screw cap as used in Liverpool, and a wire basket containing charcoal may be beneficially placed when the gas must pass through it.

Large brick sewers must not only be relieved of pressure, but must be clear enough for men to work in them.

In London we all know how they are supposed to be kept clear of foul gas, that is by the numerous open gratings which are seen in every street.

This would seem at first sight a rude method and a dangerous one. Experience, however, teaches us that the evils naturally to be expected from such a system are not so serious in practice as the nature of sewer gases would lead us to think. No doubt the diffusive property of gases has much to do with this favorable result. By the proper use of charcoal it is stated that the possible evil is reduced to a minimum.

I do not think any inseparable difficulty would be encountered in applying mechanical ventilation to sewers. Certainly there is the cost, but this should not stand in the way for a moment where the public health is concerned. Let those in authority say it must be done, and I feel sure the way would soon be found.

A sewer 6 ft. in diameter and five miles long will contain 746,000 cubic ft. of air, but after deducting one-third for space occupied by sewage water, 497,550 cubic ft. would be the quantity left to be dealt with. As mentioned above, a fan 10 ft. in diameter will remove 9,000 cubic ft. of air per minute, so that the entire quantity in the

sewer might be changed once every 56 minutes. Certainly nothing like this would be required.

Practical difficulties would, no doubt, be encountered, especially in regulating the admission of air into the sewers, the position of the fan, the construction of side entrances, gullies, etc.; but these difficulties must be encountered and overcome if we wish to apply mechanical ventilation to the sewers of London. I am aware that there is nothing new in this proposed method of ventilating sewers, as it was suggested by Mr. Gibbs, I believe in 1871, when it was met by objections that unless every gully or air hole were stopped up when the fan was at work, the air would enter the sewers at the nearest inlet with great velocity, which would diminish the further the distance was from the fan.

I think, however, it is not beyond the engineering talent of the country to devise inlets which shall admit the air to sewers in such proportions and at such places as may be required.

The difficulty would be much diminished

if a system of sewers had but one or two outlets; and if the sewers were used simply for sewage and not for surface and subsoil water, the difficulty would be very small indeed.

The same objections will, moreover, apply to any system of artificial ventilation for sewers, whether it be by the furnace or by simple ventilating shafts.

The following table, compiled by Mr. Haywood, C. E., showing the temperature of the City sewers, will not, I think, be out of place:—

Time of Year.	External Temperature in Shade.			Temperature in Sewer.			Above External Temperature.	Below External Temperature.
	Highest.	Lowest.	Mean.	High.	Low.	Mean.		
Summer.....	72°	55	65.04	68	56	61.92	.....	3.12
Winter.....	34	30	32 37	52	40	43 98	11.61	. ..
Spring	61	46	52.46	59	48	52.52	0 06	...
Autumn.....	68	48	59.90	70	53	62.97	3 07	....
Average of year.	.....	.....	50.24	.....	.....	55.35	5 11	....

The table shows us we cannot at all seasons rely on the superior temperature of the sewers for ventilation.

The last part of my subject presents fewer difficulties, I think, than the sewers.

No description of the way in which underground railways are now ventilated need be entered into.

We are all acquainted with the stifling atmosphere underground, and the choking, burning-matches odor which pervades the stations and streets near them. The insertion of iron grids in the roofs of the tunnels and the discharge of the noxious vapor and steam into the streets can hardly be considered a satisfactory solution of the question.

I believe we must here call mechanical ventilation to our aid. But first, let us consider the condition of the structure we are going to treat.

Taking one of the metropolitan railways as a type, we see it consists of a series of tunnels, and open or semi-open stations. The foul air is generated chiefly during the passage of trains through the tunnels, and

a certain quantity of this foul air is thrust into the station by the train as it enters the further end of the tunnel. This foul air, being heated, slowly ascends, filling the streets and neighboring houses.

The stations are nothing more than dwarf ventilating shafts in which the passengers are partially stifled previous to the completion of the process in the tunnel.

Having stated the conditions of the structure, let us consider what is required to be done.

First, we have a certain quantity of foul air to get rid of without harm or annoyance to the public. Secondly, the stations must be kept so clear as to allow of passengers using them with comfort. And thirdly, circulation of air should be maintained in the tunnels, which should be kept as sweet as possible, not only for the sake of the passengers, but for the workmen also, and for the greater security of the public against accidents.

It seems to me that these objects will be best accomplished by reversing the present system, turning the stations into downcast

shafts, and drawing the foul air away at the middle of the tunnels.

A little consideration will show how a series of tunnels might be connected together by what might be called air sewers, and the foul gases led to one or more pumping stations, there to be forced up high chimneys.

The pumps might be either air pumps, such as are I believe used in some Belgian collieries, or machinery similar to Nixon's ventilator, or one of the many kinds of fan.

Some of these machines are very powerful. At the navigation pit, near Aberdare, Mr. Smyth gives the theoretical quantity of air expelled per minute, by one of Nixon's machines, at 166,000 cubic ft. In Belgium many fans of enormous power are at work ventilating coal mines.

The chief difficulty is the expense, but I submit this ought not reasonably to stand in the way.

I believe, however, that a plan could be found, which would accomplish the object at no very extravagant outlay.

I have said nothing about ventilating

ordinary railway stations,—first, because it is difficult, if not impossible, to apply any system to a building which sometimes consists of but one wall, and a part of a roof; and secondly, when the station is of greater pretention, it is almost always open at both ends, and has usually a great deal too much air in it already.

Free escape for steam must be provided, and I think a good example of roof for this purpose was shown, to those of the members who visited the Great Eastern Railway extension works, on Friday last, at the low level station at Shoreditch.

In conclusion, I would again insist on the deep importance of the subject especially to Engineers and Architects. The limits of my space, not to mention other causes, have, I am well aware, prevented justice being done to it; but the object of a paper like this, is more to put forward sound principles and throw out ideas, which may when opportunity requires be worked out to good purpose, than to lay down schemes to meet every or any particular case.

All scientific men acknowledge the necessity of ventilating dwelling-houses and buildings such as are herein mentioned, but with the general public it is unfortunately far otherwise, and one of the greatest difficulties to be encountered in the progress towards a complete and perfect sanitary condition is this inertia of those most interested. Difficulties are, however, only made to be overcome, and it is in the hope of doing something, however little, towards overcoming this particular difficulty that I venture to trespass further on the patience of the reader, and I propose to confine these remarks to the sanitary condition of our houses as being the subject of most immediate importance to the general public, for ventilation of such structures as factories, railway tunnels, and sewers, though of great moment, must be left in the hands of the Engineer who designs them, each case being treated upon its own merits and with due regard to its peculiarities. All the public can do in such instances is to insist that there shall be ventilation of some sort.

All persons readily admit as a truism, that they cannot live without air, but, unfortunately, they seldom get much beyond the bare admission. Air is not treated by them as a substance requiring space as solids or liquids do, and means of passage into, or out of, rooms, churches, etc., just as much as water requires pipes or channels to allow it to flow into or out of reservoirs. With most persons air seems to be an abstract idea rather than a substance of vital consequence to the whole living creation.

I have stated in the paper that air, which has once passed through the lungs is unfit to be respired again, just as unfit as any other substance which has once passed through the system is to be used, as it were, over again. So that, were there no other source of contamination to the air of a building, ventilation would be rendered necessary by the very presence of living beings. As it is, however, there are so many other evil influences at work in most houses and other buildings that the necessity is made far more absolute.

It is usually only in times of panic, caus-

ed by the approach or presence of some fearful epidemic, or of a calamity such as last year threatened this nation, that people seriously turn their attention to sanitary matters, and at times like these they accept the wildest schemes and act upon the crudest notions until, finding matters are no better, and perhaps rather worse than before, and the fright beginning to wear off, they relapse into carelessness, and vote sanitary science all nonsense. I think defective education is responsible for a great deal of this. I do not intend to assert that the generality of people, at any rate in the upper and middle classes, are what is commonly called ignorant; probably most of those who would be willing to turn their attention to sanitary matters, not being professionally engaged in them, have had at least the usual amount of education, as the term is commonly understood. The three R's are familiar to them as are also mathematics, Greek, and Latin, and they can probably converse in one or more of the modern languages, but what may be called the science of living, *i.e.*, how life is sustain-

ed, and the reasons why sanitary matters should be so carefully attended to in order that health and strength may be insured, are things of which comparatively few know anything at all.

In this paper I wish to impress upon the reader the very great importance of pure air to the human body, and to show how such air, or as pure as the district affords, may be insured in our houses.

It has been stated before, that one of the elements of the atmosphere unites in our bodies with certain of the elements composing the food we eat. This union of elements is a true combustion, though a slow one, as true and real as the combustion of coals in a fire grate.

Our food, having been decomposed in the body, is brought into a state proper for sustaining life and animal heat in us when, as venous blood, it is submitted to the purifying action of oxygen brought into the body by the lungs. Without the element, oxygen, which I have before stated forms part of the atmosphere, this purification could never take place, for the other

gases have no power of the kind. It will be obvious upon consideration that if a portion of oxygen in the air we have breathed has united with elements composing our food, that portion is removed from the atmosphere and must be replaced if breathing is to be continued.

I will here explain for the benefit of persons who may be wholly unacquainted with chemistry, what is meant by the term "element." The ancients held that there were four elements, or simple bodies, viz., earth, air, fire and water, but the progress of chemical knowledge soon revealed the fact that these were not elementary bodies at all, three of them being compound, while the fourth, fire, may be more properly described as a condition of matter. An element is a body which cannot, as far as we know, be divided or decomposed. It is unalterable and indestructible, and is therefore called a simple body or element.

Elements, however, combine with one another, and lose their individuality, so to speak, in the compound. Thus two simple bodies, gases, hydrogen and oxygen, unite

in certain definite proportions and form water; but the water can be again decomposed into its constituents.

Air, although I have called it a compound, is not, chemically speaking, strictly so; it is a mixture of gases which preserve their individuality as sand and sugar would do if they were mixed in a vessel.

We are at present acquainted with more than sixty elements or simple bodies.

But to return to the atmosphere. It must not be imagined that we remove all the oxygen from the air we breathe; on the contrary, the removal of a small percentage renders air incapable of supporting life, and a still less diminution causes the difference between fresh air and vitiated.

I have said a good deal about the effect which the act of breathing has upon the atmosphere, because I want to make very clear the fact that the same air should not be respired more than once, and that it cannot be so, even in part, without danger to health. The other results of respiration, viz., carbonic acid and water, have been mentioned before, and it was shown that they contributed to foul the air.

I think we may, without serious error, divide noxious gases into two classes, placing those which are negatively poisonous in one class, and those which are positively, or actively, so in the other. To the former belong—as types—carbonic acid and nitrogen, both of which, though not in themselves injurious, are incapable of supporting life; so that an atmosphere composed wholly of these gases, or containing them in undue proportion, is fatal, from its negative qualities, to living beings. Carbonic acid gas, as before explained, is one of the products of combustion and respiration, while nitrogen forms 79 per cent. of the volume of the atmosphere. Its negative qualities are there, however, counterbalanced by the presence of oxygen.

With gases of the second class the case is very different. Some of them—such, for instance, as sulphuretted hydrogen and carbonic oxide—are fearfully active poisons. The former exists in putrid eggs, and some other animal and vegetable matters; also in certain waters, called *hepathic*, such as those of Harrowgate. It is usually formed

in the putrefaction of vegetable and animal matters; hence it is found in sewers, and especially in cesspools and similar places where accumulations of this filth take place. During the emptying of such receptacles, workmen sometimes suffer from asphyxia, or, as the French call it, "*le plomb*" (probably from the oppression on the chest which accompanies it). Parent Duchatelet states that the symptoms of poisoning by sulphuretted hydrogen are very alarming, for "the individual is either seized suddenly, and dies instantly, or, if the quantity of deleterious gas is too little to bring instant death, the asphyxiated person, suddenly losing consciousness, is taken with convulsive movements or other very grave nervous disturbances, and it is only after several days that he recovers perfect health." The presence of sulphuretted hydrogen is readily detected by its odor, which resembles that of rotten eggs; but it is soothing in its nature if inhaled, which renders it especially dangerous when escaping into rooms where persons are sleeping.

It will be seen, then, of what extreme

importance is the prevention of the passage of sewer gases into our houses, and I have entered somewhat fully into the properties of these foul gases, because I wish to show clearly that they are not things to be trifled with.

Carbonic oxide is, like carbonic acid, a product of the combustion of carbon, or the union of carbon with oxygen, but the proportion of oxygen is less in the former than in the latter compound. Carbonic oxide, though a dangerous gas, need not be considered at length here, as it does not, I believe, exist in sewers, and is very seldom found in houses. It cannot, like sulphuretted hydrogen, be detected by its smell, as it is inodorous as well as colorless and tasteless. Carbonic oxide burns with a blue flame, which probably most people have noticed at some time or other, either playing over burning charcoal or dancing upon an ignited lime kiln.

I must now leave this part of the subject and say a few words useful, I hope, to those who are about to choose a house, whether as tenants or purchasers, and in

doing so I may, perhaps, travel somewhat away from ventilation.

The first consideration, after settling which town or part of the country it is desired to live in, should be the situation of the house, *i.e.*, not only its aspect, but the condition of the soil on which it stands, and its position with regard to any ponds, streams, rivers, or other natural features.

Taking first the aspect. It is generally considered that a house is most favorably situated when its principal front is towards the south-east, for it then gets the morning sun, while the rooms are sheltered to a great extent from the midday heat. The south-west is the rainy quarter in the country, and should, therefore be avoided. A gravel soil is commonly to be preferred to any other, although, I believe, that in towns which are well sewered and drained, the nature of the soil is not of so much importance; indeed, one might readily imagine a case in which a gravel soil would be anything but a benefit—as, for instance, where there is a pond near the house, and on about the same level, or in towns where

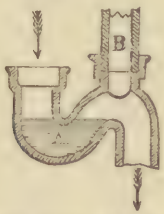
percolating cesspools are the fashion. Running water near a house is not objectionable, indeed many persons consider it rather beneficial than otherwise; but before taking the house, care should be exercised in ascertaining that the water is free from sewage contamination, especially if it be a small stream, or liable to dry up in summer. Stagnant ponds should always be avoided, especially if the house is on nearly the same level.

With regard to artificial sanitary conditions, as distinguished from natural situation, soil, etc., the first question to be asked of the landlord should be as to a good water supply to the house other than from wells on the premises. There being no such supply, nor means of laying one on, would certainly be against the house, inasmuch as where there are no water works, there is generally no system of sewerage, and it may safely be said that in any unsewered town there is hardly a well the water of which is fit to drink; to say nothing of the labor of pumping water into cisterns, etc. From this follows, naturally,

the question as to the sewerage of the town or village. If there is no system of sewers, I would say, "live anywhere else if you possibly can," for the absence of sewerage indicates the existence of some form of cesspool, an evil so great that nothing but absolute necessity should cause any person to take a house to which a cesspool is attached. I say "some form of cesspool," for I am quite aware that there are schemes which profess to do away with water-closets, and cesspools, and partially with sewers, but upon examination, they will all be found wanting in some material point. Among these plans are the "dry earth" and "pail" systems, both, in my opinion, but forms of cesspools. If the town or village is sewered, the first point is to make sure that the house drains are properly connected with the sewers. It is no uncommon thing for the drain to be carried from the house to the outside of the sewer, and to stop then, being thus rather worse than useless. The bricklayer would probably call this "leaving another job." After seeing that the connection is properly made,

i. e., that the pipe really passes into the sewer, the next thing to be done is to find out of what the house drain is made, or how it is laid. These points I have alluded to before, and shall therefore pass them over here. Next, make sure that the house drains are properly ventilated. The landlord or builder will probably tell you that they are "trapped" and that no foul gas can pass the trap. This is a great delusion, and should not be listened to for a moment. The trap is a very useful and necessary thing, but it must not be expected to do more than it can, and in order to make this clear, I will explain what the common siphon trap is, viz., a bent pipe generally of the form shown in section in the sketch.

FIG. 7.



The common trap has not the ventilating pipe B.

These pipes always retain a certain quantity of water (indicated by shading in the figure) when in use, in the dip or bend. It will be observed that the upper part of the pipe dips into the water which completely fills the bend, and the water is sometimes said to "seal" the trap, and it is assumed that it will entirely prevent any gases from passing into the house. A little consideration will show, however, that if the gas is generated in such quantities as to cause any considerable pressure in the sewers, it will readily pass through the water into the house. That this has actually happened, the following incident recorded by Dr. Carpenter will show. The ventilating pipe spoken of was in fact doing duty as a water-pipe from the cistern! "On the night of October 17th I was aroused by a loud noise proceeding from the closet; it continued at intervals throughout the next day. Unable at first to account for it, I eventually found that it was caused by the ventilating pipe doing duty as water-pipe to the overflowing cistern (during a very heavy rainfall). There was no room for

exit of foul air from the sewer, which, therefore, was forced through the trap of the water-closet, with, at times, the force of steam through the safety-valve of a steam-engine. The nuisance continued for nearly three days before the weather would allow the plumber to rectify a mistake which had been committed in the previous summer, the mistake of making the ventilating-pipe do duty for a water-pipe." Dr. Carpenter then says that owing to there being no particular smell, this escape was tolerated, but in two or three days the occupants of the house were attacked by typhoid fever, and that in many other parts of the town enteric disease appeared at the same time.

The traps should be ventilated, and the ventilating pipe should *not* open into the house. I know no better means of ventilating the traps than that I have before described, and as shown in the figure above. In this A is the trap and B the ventilating pipe, the arrows indicate the direction of the flow of sewage from the house to the sewers. It will be obvious that if any accumulation of gas takes place

in the sewers, it will pass up the ventilating pipe B, instead of forcing the trap and flowing into the house. Therefore, insist on the drains being ventilated, or do not take the house.

There are several kinds of trap, but the principle of all is nearly the same.

Having settled these preliminaries, let us consider the house itself, and examine it carefully.

I need hardly say that this can scarcely be done satisfactorily by the intending tenant or purchaser, unless he has a far greater knowledge of building and sanitary matters than falls to the lot of most non-professional men, but much may be accomplished by the diligent use of eyes, and nose especially, if they are used in the right way.

The foundations and basement may reasonably claim attention first. Under all the walls there should be a mass of good concrete, and the whole area on which the house stands should be covered with the same in a layer, not less than 6 in. thick. This layer of concrete, if made with good

hydraulic lime, or better still, Portland cement, will not only prevent damp from rising into the house, but will keep out those domestic pests, rats, mice, and black-beetles as well. In all damp soils concrete under all basement floors should be insisted upon. If it is not there, and the landlord will not put it, do not take the house.

Next, note the thickness of the walls. If any external brick wall is less than 14 in. thick, the house will always be damp and uncomfortable. Examine the water-closets, especially as to position. I have already entered into this question, and will not therefore say any more about it here. Look to the water cisterns, and find out where the waste pipes go to. If into the soil pipe of the water-closet, or into the drain, as is commonly the case, have them altered at once. Dr. Carpenter's experience will give a reason for this. Both rain-water pipes and waste-pipes from the cisterns should not run directly into the drain, but should have their ends visible outside the house, and above the ground.

Under each of these pipes there should be a trapped sink, connected either with the house drains, or, in certain cases, with separate ones. By the regulations made under "The Metropolis Water Act, 1871," in all parts of the Metropolis where the Water Companies give a constant supply of water, the waste pipes from all cisterns are to be converted into warning pipes, and the outlets of such pipes are to be so placed that the officers of the Companies can readily ascertain when water is flowing from them. This regulation is intended to prevent unnecessary waste of water.

Lastly, the rooms must be considered. They should, if possible, be both light and lofty; for, low, dark rooms are depressing and unhealthy, and should therefore be avoided. All the rooms, without exception, should be efficiently ventilated, not by open windows or doors alone, since, for full half the year, an open window is impossible in England, but by some plan which shall be independent of both, for we cannot, unfortunately, suspend our breathing whenever it is necessary to close door and window,

although the majority of house builders seem, if one may judge from their works, to think it the most common-place operation in nature.

An instance of this want of forethought lately came within my knowledge. Some persons who were interested in the establishment of a particular trade in the metropolis, built a small factory for the purpose, and, as usual, ventilation was left to chance. The number of persons employed, however, brought the firm under the "Factories Act," and the Inspector insisted that ventilation should be provided. The owners, being in a difficulty, sent for a carpenter and joiner, as the most likely person to help them out of it; he naturally recommended the execution of sundry carpenter and joiner's work, and proceeded to make all the windows to open, which up to that time had been, very properly, fixed. The immediate result of this was that half the persons employed caught violent colds, and the ventilation was quite a failure, for the next time the Inspector called, being a wet, windy day, all the windows were closed, and

he, not unnaturally, concluding that nothing had been done, preremptorily called upon the owners to remedy the insalubrious state of affairs. They again called the carpenter to their aid, who, resolving this time either to kill or cure, cut a large square hole in the ceiling and roof and put up a kind of lantern, with louvre board sides, over it. Probably he intended this for an exit, but having made no provision for the inlet, the cold air came down upon the heads of those who sat below quite as fast as any foul air went out.

There is nothing more injurious than want of ventilation, except perhaps a draught of cold air. Proper ventilation should never cause draught.

Intending tenants will do well to get the necessary sanitary conditions complied with, before they enter into possession. Some landlords will promise great things before the tenant is actually in the house, but after that will do nothing whatever, and the unfortunate occupier finds himself obliged, either to make alterations at his own expense, put up with annoyance, ill health, and,

may be, the death of some of his family, or, at great inconvenience, leave the house, and, perhaps, risk an action at law with the landlord.

If the landlord decline to make the necessary alterations before the tenant enters into possession, have nothing to do with the house.

To the case of inhabited houses, where ventilation or other sanitary matters are defective, most of what has gone before will apply. I would urge all persons not to allow defects in drainage or ventilation to exist an hour longer than is absolutely necessary. How many outbreaks of cholera can be traced to a defective drain or foul cesspool, and people have said "Oh, it is in the air," or in this, or in that, while the real cause was, perhaps, under their very feet.

With regard to country houses, which, from their isolated position, are beyond the reach of a system of sewerage, it must be admitted that many difficulties are presented to us.

Sewage must be disposed of by irrigation

on the land, for there is no other successful method of dealing with it at present known, and therefore towns and villages have been empowered by various Acts of Parliament to acquire land for this purpose. Private persons have not this advantage and in their case the cesspool has always, until lately, been regarded as the only resource. But it is a very dangerous resource. Ask how the liquid gets away from the cesspool and you will probably be told that it percolates through the brickwork forming the sides, the bricks being laid dry on purpose, and passes into the surrounding soil. Yes, percolates under our houses, into the springs, pollutes the wells, until, as at Rugby before the sewerage works were executed, things come to such a pass that the fluid thrown into the cesspool in the morning is pumped from the well at night! Or, perhaps, the cesspool is well built and the sewage retained in it, but the mass of putrid filth must be taken away, and I suppose many persons have been disgusted at some time or other with this sickening process.

The remedy is not hard to find, but the

means to be adopted will depend greatly upon the conditions of each individual case. Moreover, this belongs to another branch of sanitary science, and I am wandering away from ventilation.

What has been said with respect to ventilating drains connected with sewers will apply with more force where there are cesspools. For in the former case there may be no evolution of foul and dangerous gases even for years, while in the latter it is certain and continuous.

It is of no use to try and enclose it in the cesspool, free vent must be given if you would keep death and disease out of your houses.

In concluding these somewhat disjointed observations on a very important subject, I would ask the reader to remember that the whole paper has been written at different times, when a few moments could be spared from more pressing matters, and if I have not adhered strictly to ventilation, pure and simple; yet drainage and warming are so intimately connected with it, that it is difficult to treat of one without drawing in the others also.

Very much more might have been said about ventilating public buildings, such as churches for instance, where no attempt seems ever made to get fresh air in, or foul gas out of the building, but I have simply endeavored to convey a little useful information to the reader, which will, I hope, be of service in improving domestic comfort, and keeping disease away from our homes.

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